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High-frequency seismic interferometry: broadband measurements of surface-wave phase velocities using "large-N" arrays

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High-frequency seismic surface waves sample the top few tens of meters to the top few kilometres of the subsurface. They can be used to determine three-dimensional distributions of shear-wave velocities and to map the depths of discontinuities (interfaces) within the crust. Passive seismic imaging, using ambient noise as the source of signal, can thus be an effective tool of exploration for mineral, geothermal and other resources, provided that sufficient high-frequency signal is available in the ambient noise wavefield and that accurate, high-frequency measurements can be performed on this signal. Ambient noise imaging using the ocean-generated noise at 5-30 s periods is now a standard method, but less signal is available at frequencies high enough for deposit-scale imaging (0.2-30 Hz), and few studies have reported successful measurements in broad frequency bands. Here, we develop a workflow for the measurement of high-frequency, surface-wave phase velocities in very broad frequency ranges. Our workflow comprises (1) a new noise cross-correlation procedure that accounts for the non-stationary properties of the high frequency noise sources, removes bandpass filtering, replaces temporal normalization with short time window stacking, and drops the explicit spectral normalization by adopting cross-coherence; (2) a new phase-velocity measurement method that extends the bandwidth of reliable measurements by exploiting the (resolved) 2π ambiguity of phase-velocity measurements; (3) interstation-distance-dependent quality control that uses the similarity of subgroups of dispersion curves to reject outliers and identify the frequency ranges with accurate measurements. The workflow is highly automated and applicable to large arrays. Applying our method to data from a large-N array that operated for one month near Marathon, Ontario, Canada, we use rectangular subarrays with 150-m station spacing and, typically, 1 hour of data and obtain Rayleigh-wave phase-velocity measurements in a 0.55-23.8 Hz frequency range, spanning over 5.4 octaves, nearly twice the typical frequency range of 1.5-3 octaves in previous studies. Phase-velocity maps and the subregion-average 1D velocity models they constrain show a high-velocity anomaly consistent with the known, west-dipping gabbro intrusions beneath the area. The new structural information can improve our understanding of the geometry of the gabbro intrusions, hosting the Cu-PGE Marathon deposit.